

WHAT IS CLAIMED IS:

1. A logging tool for a borehole, the borehole having an interior wall, the logging tool comprising:
a tool body adapted to be inserted into the borehole;
a sensing device coupled to the tool body, the sensing device adapted to detect radial flow of conductive
5 fluid entering or leaving the borehole interior wall, the sensing device being adapted to detect the conductive fluid flow adjacent the borehole interior wall;
shields disposed along the sensing device; and
voltage sensing electrodes disposed on the interior surfaces of the shields.
2. The logging tool of claim 1, wherein the shields are interconnected.
- 10 3. The logging tool of claim 1, wherein the shields comprise a conduit through which fluid may flow.
4. The logging tool of claim 1, wherein the voltage sensing electrodes comprise a point electrode.
5. The logging tool of claim 1, wherein the voltage sensing electrodes comprise a longitudinal electrode.
6. The logging tool of claim 1, wherein the voltage sensing electrodes substantially cover opposing sides of the shields.
- 15 7. A fluid flow measuring device, comprising:
a plurality of resistors disposed in a circular pattern;
a plurality of shields disposed along the fluid flow measuring device in a circular pattern;
a plurality of electrodes, each electrode coupled between two adjacent resistors and disposed on an interior surface wall of one of the shields;
20 a first coil of wire adapted to generate a magnetic field wound proximate the resistors and electrodes;
a second coil of wire adapted to generate a magnetic field wound proximate the resistors and electrodes;
and
a voltage measuring mechanism electrically coupled between two of the resistors, wherein a flow of conductive fluid is detectable by measuring the voltage.
- 25 8. The fluid flow measuring device of claim 7, wherein the shields are interconnected.

9. The fluid flow measuring device of claim 7, wherein the shields comprise a conduit through which fluid may flow.
10. The fluid flow measuring device of claim 7, wherein the electrodes comprise a point electrode.
11. The fluid flow measuring device of claim 7, wherein the electrodes comprise a longitudinal electrode.
- 5 12. The fluid flow measuring device of claim 7, wherein the electrodes substantially cover opposing sides of the shields.
13. A method of measuring radial fluid flow in a borehole having an interior wall, the method comprising:
traversing the borehole with a tool body having a sensor loop attached thereto, wherein shields are disposed
along the sensor loop, and wherein voltage sensing electrodes are disposed on the interior surfaces of the shields;
10 and
detecting a radial flow of conductive fluid entering or leaving the borehole interior wall.
14. The method of claim 13, wherein the shields are interconnected.
15. The method of claim 13, wherein the shields comprise a conduit through which fluid may flow.
16. The method of claim 13, wherein the voltage sensing electrodes comprise a point electrode.
- 15 17. The method of claim 13, wherein the voltage sensing electrodes comprise a longitudinal electrode.
18. The method of claim 13, wherein the voltage sensing electrodes substantially cover opposing sides of the shields.
19. A fluid flow measuring device, comprising:
a plurality of shields disposed along a curved loop;
20 a series-coupled plurality of alternating electrodes and resistors, wherein each of the electrodes is disposed on an interior surface wall of one of the shields;
a magnetic field source, the magnetic field source oriented to generate a magnetic field between adjacent electrodes, the magnetic field substantially orthogonal to an imaginary line intersecting the adjacent electrodes; and

a voltage measuring circuit electrically coupled to the plurality of alternating electrodes and resistors, the voltage measuring circuit coupled to measure a voltage difference between the adjacent electrodes, the voltage difference representative of a radial flow of conductive fluid substantially orthogonal to both the imaginary line and the magnetic field.

- 5 20. The fluid flow measuring device of claim 19, wherein the shields are interconnected.
21. The fluid flow measuring device of claim 19, wherein the shields comprise a conduit through which fluid may flow.
22. The fluid flow measuring device of claim 19, wherein the electrodes comprise a point electrode.
23. The fluid flow measuring device of claim 19, wherein the electrodes comprise a longitudinal electrode.
- 10 24. The fluid flow measuring device of claim 19, wherein the electrodes substantially cover opposing sides of the shields.

25. A method of manufacturing a fluid flow measuring device, the method comprising:
disposing a plurality of shields on a sensor loop;
disposing a plurality of electrodes on interior surface walls of the shields;
disposing a plurality of resistors on the sensor loop;
5 electrically coupling the electrodes and resistors in an alternating series;
disposing a magnetic field source on the sensor loop proximate the electrodes, wherein the magnetic field source is oriented to generate a magnetic field substantially orthogonal to an imaginary line intersecting adjacent electrodes; and
electrically coupling a voltage measuring circuit to the plurality of alternating electrodes and resistors, the
10 circuit coupled to measure a voltage difference between adjacent electrodes, the voltage difference representative of a radial flow of conductive fluid substantially orthogonal to both the imaginary line and the magnetic field.
26. The method of claim 25, wherein the shields are interconnected.
27. The method of claim 25, wherein the shields comprise a conduit through which fluid may flow.
28. The method of claim 25, wherein the electrodes comprise a point electrode.
- 15 29. The method of claim 25, wherein the electrodes comprise a longitudinal electrode.
30. The method of claim 25, wherein the electrodes substantially cover opposing sides of the shields.
31. An inspection tool for a casing, the casing having an interior wall, the inspection tool comprising:
a tool body adapted to be inserted into the casing;
an electromagnetic sensing device coupled to the tool body, the electromagnetic sensing device having a
20 plurality of electrodes positioned substantially equidistance from the interior wall and having a plurality of shields, each shield comprising a conduit through which fluid may flow and having a plurality of the electrodes therein; and
a magnetic field generator coupled to the tool body, the magnetic field generator adapted to generate a magnetic field substantially perpendicular to an imaginary line between two adjacent electrodes;
wherein the electromagnetic sensing device is adapted to measure an induced voltage caused by an inflow
25 or outflow of conductive fluid through the interior wall of the casing.

32. The inspection tool according to claim 31, wherein the magnetic field is an alternating magnetic field.

33. The inspection tool according to claim 31, wherein the electromagnetic sensing device comprises a sensor loop, the sensor loop being adapted to exert outward pressure to maintain the sensor near the interior wall of the casing while the tool traverses the casing.

5 34. The inspection tool according to claim 33, wherein the sensor loop includes a spring disposed within the sensor loop to exert outward pressure.

35. The inspection tool according to claim 33, wherein the sensor loop is a continuous ring, wherein an inflow or outflow of conductive fluid is detectable along the circumference of the sensor loop.

10 36. The inspection tool according to claim 33, wherein the magnetic field generator comprises:
a first coil of wire adapted to generate a magnetic field proximate the sensor loop;
a second coil of wire adapted to generate a magnetic field proximate the sensor loop;
a ferromagnetic material disposed between the two coils; and
an alternating current generator coupled to the first coil and the second coil.

15 37. The inspection tool according to claim 31, wherein the electromagnetic sensing device further comprises:
a plurality of resistors, at least one resistor being coupled between two adjacent electrodes; and
a voltage measuring mechanism electrically coupled between two of the resistors.

38. The inspection tool according to claim 31, wherein the magnetic field generator comprises a first coil and a second coil.

20 39. The inspection tool according to claim 31, wherein the electromagnetic sensing device is coupled to the tool body at a loop high point and a loop low point, the loop high point and loop low point being about 180 degrees apart along the electromagnetic sensing device.

40. The inspection tool according to claim 31, wherein the electromagnetic sensing device is relatively insensitive to a flow of conductive fluid along a longitudinal axis of the casing.

41. An inspection tool for detecting a radial flow of conductive fluid through a casing, the inspection tool comprising:

a tool body adapted to be inserted into the casing;

an electromagnetic sensing device coupled to the tool body, the electromagnetic sensing device having a plurality of electrodes and a plurality of shields, each shield having a plurality of electrodes therein; and

a magnetic field generator adapted to generate a magnetic field substantially perpendicular to the imaginary line between two adjacent electrodes;

wherein the plurality of electrodes are oriented to detect the radial flow of conductive fluid through the casing.

42. The inspection tool according to claim 41, wherein the magnetic field generator generates an alternating magnetic field.

43. The inspection tool according to claim 41, wherein the electromagnetic sensing device comprises a sensor loop, the sensor loop being adapted to exert outward pressure to maintain the sensor near the casing interior wall while the tool traverses the casing.

44. The inspection tool according to claim 43, wherein the sensor loop includes a spring disposed within the sensor loop to exert outward pressure.

45. The inspection tool according to claim 43, wherein the sensor loop is a continuous ring, wherein an inflow or outflow of conductive fluid is detectable along the circumference of the sensor loop.

46. The inspection tool according to claim 43, wherein the magnetic field generator comprises:
a first coil of wire adapted to generate a magnetic field proximate the sensor loop;
a second coil of wire adapted to generate a magnetic field proximate the sensor loop;
a ferromagnetic material disposed between the two coils; and
an alternating current generator coupled to the first coil and the second coil.

47. The inspection tool according to claim 41, wherein the electromagnetic sensing device further comprises:
a plurality of resistors, at least one resistor being coupled between two adjacent electrodes; and
a voltage measuring mechanism electrically coupled between two of the resistors.

48. The inspection tool according to claim 41, wherein the alternating magnetic field generator comprises a first coil and a second coil.

49. The inspection tool according to claim 41, wherein the electromagnetic sensing device is coupled to the tool body at a loop high point and a loop low point, the loop high point and loop low point being about 180 degrees apart along the electromagnetic sensing device.

50. The inspection tool according to claim 41, wherein the electromagnetic sensing device is relatively insensitive to a flow of conductive fluid along a longitudinal axis of the casing.

51. A method of measuring radial fluid flow in a casing having an interior wall, the method comprising:
traversing the casing with a tool body having a plurality of electrodes and a plurality of shields, each shield comprising a conduit through which fluid may flow and having two or more electrodes therein;
generating a magnetic field substantially perpendicular to an imaginary line between adjacent electrodes;
and
measuring an induced voltage indicative of a substantially radial flow of conductive fluid entering or leaving the casing interior wall.

52. The method according to claim 51, wherein the magnetic field is an alternating magnetic field.

53. The method according to claim 51, further comprising maintaining the plurality of electrodes near the interior wall of the casing.

54. The method according to claim 51, wherein the plurality of electrodes are positioned on a sensor loop, and further comprising adjusting the sensor loop such that the sensor loop fits within the casing.

55. The method according to claim 54, wherein the adjusting includes changing the angle of the sensor loop with respect to a central axis of the casing.

56. A fluid flow measuring device, comprising:
a plurality of resistors disposed in a circular pattern;
a plurality of electrodes, at least one resistor being coupled between two adjacent electrodes;
a plurality of shields having two or more of the electrodes therein;

a pair of coils adapted to generate a magnetic field proximate the resistors and electrodes, the pair of coils being substantially parallel to each other; and

a voltage measuring mechanism electrically coupled between two of the resistors, wherein the voltage measuring mechanism measures an induced voltage indicative of a flow of conductive fluid between two electrodes.

5 57. The fluid flow measuring device according to claim 56, wherein the magnetic field is an alternating magnetic field.

58. The fluid flow measuring device according to claim 56, wherein the pair of coils are electrically coupled to an alternating current source.

59. The fluid flow measuring device according to claim 56, further comprising a ferromagnetic material
10 disposed between the two coils.

60. The fluid flow measuring device according to claim 59, wherein the ferromagnetic material comprises an iron alloy.

61. The fluid flow measuring device according to claim 56, wherein at least the resistors and electrodes are mounted on a sensor loop, the sensor loop being spring-loaded and being adapted to exert outward pressure to
15 maintain the sensor loop near a casing interior wall.

62. The fluid flow measuring device according to claim 61, further comprising:
means for maintaining the sensor loop near the casing interior wall over a range of casing diameters.

63. The fluid flow measuring device according to claim 61, wherein the sensor loop comprises a body comprising fluoropolymer resin.

20 64. The fluid flow measuring device according to claim 61, wherein the sensor loop is spring-loaded with a stainless steel spring wire.

65. The fluid flow measuring device according to claim 61, wherein the sensor loop has a substantially oval shape.

66. The fluid flow measuring device according to claim 56, wherein the coils comprise copper.

67. The fluid flow measuring device according to claim 56, wherein the plurality of resistors comprise values of between about 500,000 ohms and about 2,500,000 ohms.

68. The fluid flow measuring device according to claim 56, wherein at least the resistors and electrodes are mounted on a sensor loop, the sensor loop being spring-loaded to maintain the sensor loop near an interior wall of a fluid conduit.

69. A fluid flow measuring device, comprising:

a series-coupled plurality of electrodes and resistors such that one or more resistors are coupled between adjacent electrodes;

a plurality of shields having two or more of the electrodes therein;

a magnetic field source, the magnetic field source oriented to generate a magnetic field between adjacent electrodes, the magnetic field substantially orthogonal to an imaginary line intersecting adjacent electrodes; and

a voltage measuring circuit electrically coupled to the plurality of electrodes and resistors, the voltage measuring circuit coupled to measure a voltage difference between adjacent electrodes, the voltage difference representative of a flow of conductive fluid through the magnetic field.

70. The fluid flow measuring device according to claim 69, wherein the magnetic field is an alternating magnetic field.

71. The fluid flow measuring device according to claim 69, wherein the electrodes are disposed along a curved loop

72. The fluid flow measuring device according to claim 69, wherein the magnetic field source includes an alternating current source.

73. The fluid flow measuring device according to claim 69, wherein the voltage difference is proportional to a velocity of the radial flow of conductive fluid.

74. The fluid flow measuring device according to claim 69, wherein the magnetic field source comprises a first coil of wire proximate the electrodes.

75. The fluid flow measuring device according to claim 74, wherein the magnetic field source further comprises a second coil of wire proximate the electrodes and offset from the first coil of wire.

76. The fluid flow measuring device according to claim 75, wherein the magnetic field source further comprises a ferromagnetic material disposed between the first coil of wire and the second coil of wire.

5 77. The fluid flow measuring device according to claim 69, wherein the adjacent electrodes are spaced about 0.3 inches or less from each other.

78. The fluid flow measuring device according to claim 69, wherein the electrodes are mounted on a sensor loop, the sensor loop comprising a force loop exerting outwardly directed radial force.

79. The fluid flow measuring device according to claim 69, wherein the resistors comprise values of between
10 about 500,000 ohms and about 2,500,000 ohms.

80. A method of manufacturing a fluid flow measuring device, the method comprising:
disposing a plurality of electrodes spaced apart on a sensor loop;
disposing a plurality of resistors on the sensor loop;
disposing a plurality of shields having two or more electrodes therein;
15 electrically coupling the electrodes and one or more resistors in an alternating series;
disposing a magnetic field source on the sensor loop proximate the electrodes, wherein the magnetic field source is oriented to generate an magnetic field substantially orthogonal to an imaginary line intersecting adjacent electrodes; and
electrically coupling a voltage measuring circuit to the plurality of alternating electrodes and resistors, the
20 voltage measuring circuit coupled to measure a voltage difference between adjacent electrodes, the voltage difference representative of a radial flow of conductive fluid substantially orthogonal to both the imaginary line and the magnetic field.

81. The method of claim 80, wherein the magnetic field is an alternating magnetic field.

82. The method of claim 80, wherein the disposing the magnetic field source further comprises:
25 disposing a first coil of wire on the sensor loop proximate the electrodes; and

disposing a second coil of wire on the sensor loop proximate the electrodes and offset from the first coil of wire.

83. The method of claim 82, wherein the disposing the magnetic field source further comprises disposing a ferromagnetic material between the first coil of wire and the second coil of wire.

5 84. The method of claim 80, wherein the electrodes are positioned along the exterior of the sensor loop.

85. The method of claim 80, wherein the electrodes are disposed on a surface of the sensor loop.

86. The method of claim 80, wherein the resistors and the magnetic field source are disposed under a surface of the sensor loop.

10 87. The method of claim 80, wherein the electrically coupling of the electrodes and resistors is performed before the disposing of the plurality of electrodes and the disposing of the plurality of resistors.

88. The method of claim 80, wherein the electrodes are regularly spaced on the sensor loop.

89. The method of claim 88, wherein adjacent electrodes are spaced about 0.3 inches or less from each other.

90. The method of claim 80, further comprising disposing a force loop on the sensor loop, wherein the force loop exerts outwardly directed radial force.

15 91. The method of claim 80, wherein the sensor loop has a substantially oval shape.